Crossbreds of Jersey × Holstein Compared with Pure Holsteins for Production, Fertility, and Body and Udder Measurements During First Lactation

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ABSTRACT

Jersey × Holstein crossbreds (J×H; $n = 76$) were compared with pure Holsteins ($n = 73$) for 305-d milk, fat, and protein production; conception rate; days open; proportion of cows pregnant within fixed intervals postpartum; and body and udder measurements during first lactation. Cows were housed at 2 research locations of the University of Minnesota and calved from September 2003 to May 2005. The J×H were mated to Montbeliarde sires, and Holstein cows were mated to Holstein sires. Best Prediction was used to determine actual production (milk, fat, and protein) for 305-d lactations with adjustment for age at calving, and records less than 305 d were projected to 305 d. The J×H (274 kg) and pure Holsteins (277 kg) were not significantly different for fat production, but J×H had significantly less milk (7,147 vs. 7,705 kg) and protein (223 vs. 238 kg) production than pure Holsteins. The J×H had significantly fewer days open than pure Holsteins (127 vs. 150 d). Also, a significantly greater proportion of J×H were pregnant at 150 and 180 d postpartum than pure Holsteins (75 vs. 59% and 77 vs. 61%, respectively). The J×H had significantly less body weight (60 kg) at calving, but significantly greater body condition (2.80 vs. 2.71). Furthermore, J×H had significantly less udder clearance from the ground to the bottom of the udder than pure Holsteins (47.7 vs. 54.6 cm), and greater distance between front teats (15.8 vs. 14.0 cm) than pure Holsteins during first lactation.

Key words: crossbreeding, heterosis, Jersey

INTRODUCTION

Success of selection for milk production has contributed to the domination of the Holstein breed around the world. However, crossbreeding is a topic of growing interest in recent years in response to dairy producers'

concerns about fertility, cow health, and calf survival (Funk, 2006). In a survey by Weigel and Barlass (2003), dairy producers indicated crossbreeding improved fertility, survival, and profitability of dairy cows.

Many research studies have documented the effects of crossbreeding in dairy cattle, but most studies are dated (Bereskin and Touchberry, 1966; McDowell, 1982; Touchberry, 1992; McAllister et al., 1994). A crossbreeding study conducted at the University of Illinois (Touchberry, 1992) concluded that pure Holsteins were superior to Guernsey × Holstein crossbreds for milk production, but crossbreds exceeded purebreds on an economic basis. Income produced per cow per lactation was 14.9% greater for crossbreds than the average of the purebreds in the Illinois study. McAllister (2002) reported that crossbreds of Ayrshire and Holstein were similar to pure Holsteins for milk production, and 2 crossbred groups from crosses of Ayrshire with Holstein had similar economic return compared with pure Holsteins.

First-generation crosses of 2 breeds (F_1) comprise 1.2% of cows recently evaluated by the Animal Improvement Programs Laboratory (AIPL) of USDA (VanRaden et al., 2007). Fat and protein production was similar for Jersey × Holstein crossbreds (J×H) compared with pure Holsteins in the United States (VanRaden and Sanders, 2003), and J×H were more profitable for Net Merit and Cheese Merit than were pure Holsteins. Lesmeister et al. (2000a,b) reported that J×H had significantly less milk and protein production than pure Holsteins; however, the breed groups were not different for fat production.

Crossbreeding of the Jersey and Holstein breeds is common in New Zealand, and many studies have assessed the benefits of crossbreeding in pastoral systems. Ahlborn-Breier and Hohenboken (1991) reported that J×H were superior to pure Holsteins for fat production. In a more recent study, Bryant et al. (2007) concluded that J×H in New Zealand had greater fat and protein production than pure Holsteins due to heterosis. The University of Wisconsin reported that crossbred calves had lower birth weights, less calving difficulty, fewer

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stillbirths, and lower incidence of scours than pure Holstein calves (Maltecca et al., 2006).

Reduction in fertility, health, and survival of pure Holsteins led managers of 7 large commercial dairies in California to begin crossbreeding of pure Holsteins, and Heins et al. (2006a) reported that Scandinavian Red-sired calves had significantly less calving difficulty and fewer stillbirths than Holstein-sired calves. Furthermore, Scandinavian Red $\times$ Holstein and Montbeliarde $\times$ Holstein crossbred cows had significantly less calving difficulty and fewer stillbirths than pure Holsteins at first calving. Scandinavian Red $\times$ Holstein crossbred cows were not significantly different from pure Holstein cows for fat plus protein production; however, Normande $\times$ Holstein and Montbeliarde $\times$ Holstein crossbred cows were significantly lower for fat plus protein than pure Holsteins during first lactation (Heins et al., 2006c). Also, Normande $\times$ Holstein, Montbeliarde $\times$ Holstein, and Scandinavian Red $\times$ Holstein crossbreeds had significantly fewer days open than pure Holsteins, and all crossbred groups in the study survived longer than pure Holsteins during first lactation (Heins et al., 2006b).

The objectives of this study were to determine differences between J $\times$ H and pure Holsteins during first lactation for 305-d milk, fat, and protein production; SCS; conception rate (**CR**); days open (**DO**); proportion of cows pregnant (**PP**) within fixed intervals postpartum; and body and udder measurements in 2 research locations at the University of Minnesota.

MATERIALS AND METHODS

Experimental Design

The Dairy Cattle Teaching and Research Facility on the St. Paul campus (**SP**) of the University of Minnesota has a 90-head tie-stall facility, and the West Central Research and Outreach Center, Morris (**MO**) has a 150-head low-input grazing research facility, and these 2 locations share a crossbreeding design. Crossbreeding began in December 2000 with the mating of 50% of pure Holstein cows and heifers at both locations to Jersey AI sires and the other 50% to Holstein AI sires. Heifers and cows at both locations were paired by age and sire, and 1 member of each pair was randomly assigned to 1 of the 2 breeding groups. Jersey sires were randomly mated to Holstein heifers and cows, but inbreeding coefficients were not allowed to surpass 6.25% for matings of Holstein heifers and cows with Holstein sires.

Jersey and Holstein service sires were selected based on Net Merit within breed, with consideration of semen price and availability, and 3 sires were selected per year from each breed. Both locations breed seasonally; cows at SP calve in the fall and cows at MO calve mostly in the spring with some calving in the fall. All virgin heifers

are reared and bred at MO. The mating design was used for 2 yr, and all resulting J $\times$ H were bred to Montbeliarde sires, and their pure Holstein contemporaries were mated to Holstein sires.

Data

Pure Holstein heifers and cows bred to Jersey or Holstein sires calved from September 2001 to September 2003. From the foundation pure Holsteins, 98 J $\times$ H and 91 pure Holstein heifer calves were born. Two J $\times$ H and 3 pure Holstein heifer calves were stillborn; and 2 J $\times$ H calves and 1 pure Holstein heifer calf were freemartins; therefore, 94 J $\times$ H and 87 pure Holstein live heifer calves remained. Three heifers from each breed group were removed from the study for health reasons before 12 mo of age; consequently, the numbers of heifers at 1 yr of age were 91 J $\times$ H and 84 pure Holsteins. Five J $\times$ H heifers and 2 pure Holstein heifers were culled due to infertility; therefore, 86 J $\times$ H and 82 pure Holsteins calved for the first time from September 2003 to November 2005. Three J $\times$ H and 2 Holstein first-calf heifers were culled as a result of calving injuries, and 1 J $\times$ H and 2 pure Holsteins were culled before the first test day for DHI. The J $\times$ H cow was culled for a leg injury, and the 2 pure Holstein cows were culled as a result of gangrene mastitis. One J $\times$ H and 1 pure Holstein were eliminated from the study because they did not calve until 34 and 35 mo, respectively, of age.

Season of calving was spring (March to June) or fall (October to January). However, 2 J $\times$ H calved in the summer of 2003, and 3 J $\times$ H calved in the fall of 2005 at MO without pure Holstein contemporaries, and 4 pure Holsteins calved in the fall of 2005 at SP without J $\times$ H contemporaries; therefore, these 9 animals were removed from the study. All calvings at SP were in fall 2004 for this study. At MO, cows calved in fall 2003, spring 2004, and spring 2005. All J $\times$ H and pure Holsteins calved within each of these 4 location-seasons of calving (1 at SP and 3 at MO). Following edits, 76 J $\times$ H (24 at SP and 52 at MO) and 73 pure Holstein (18 at SP and 55 at MO) first-calf heifers remained for comparison.

Genetic Level of Sires of Cows

The number of daughters of sires; PTA for production, type, and functional traits; and Net Merit of sires, as well as weighted averages, are in Table 1. The PTA for production traits, functional traits, and Net Merit were obtained from the May 2007 genetic evaluation of AIPL (<http://aipl.arsusda.gov>). The PTA for type traits were obtained from the May 2007 genetic evaluation of the American Jersey Cattle Association (<http://greenbook.usjersey.com>) and the Holstein Association USA (<http://www.holsteinusa.com>).

Table 1. Number of daughters, PTA for production (kg), type and functional traits, and Net Merit, and weighted averages for sires from May 2007 genetic evaluations¹

Sire	n	PTA								
		Milk	Fat	Protein	SCS	PL	DPR	NM\$	FA	UD
Holstein										
14HO2759 Burke	13	558	18	21	2.83	-0.2	0.0	235	-1.12	-2.25
29HO7949 Decision	18	429	17	18	3.21	1.9	-2.3	189	-3.22	-2.67
29HO8343 Convincer	21	412	20	11	3.13	-2.2	-2.1	83	0.47	0.03
1HO5315 Saturn	6	793	19	19	2.86	-4.0	-1.7	170	-1.29	0.14
1HO6020 Orion	6	151	32	15	2.96	1.6	0.4	437	1.60	1.27
9HO2271 Mike	9	908	12	23	2.53	4.6	1.3	491	0.07	0.34
Weighted average		513	19	17	2.99	0.2	-1.1	223	-0.82	-0.89
Jersey										
1JE1325 Bold	17	590	20	15	2.87	1.9	-2.2	233	-1.5	-1.7
7JE386 Declo	14	239	-5	8	3.05	-0.5	0.4	32	-0.2	-0.5
7JE424 Freedom	18	192	7	-3	3.17	-2.3	-2.4	-109	0.8	0.6
7JE442 Paramount	10	202	13	11	3.04	2.7	0.4	262	0.9	0.1
29JE3194 Steadfast	9	715	12	20	3.38	-1.8	-1.3	64	0.0	-3.2
122JE5127 Fanclub	8	9	8	10	3.12	-3.1	-2.6	-24	0.3	-1.5
Weighted average		334	9	9	3.08	-0.4	-1.4	72	-0.03	-0.85

¹PL = productive life; DPR = daughter pregnancy rate; NM\$ = Net Merit; FA = foot angle; UD = udder depth.

The weighted means of PTA for sires of the J×H were +334 kg of milk, +9 kg of fat, and +9 kg of protein and the weighted means of PTA for sires of the pure Holstein cows were +513 kg of milk, +19 kg of fat, and +17 kg of protein. The weighted means of PTA for Jersey sires were similar to those of Holstein sires for SCS, productive life (**PL**), and daughter pregnancy rate (**DPR**); however, the weighted mean for Net Merit was \$151 lower for Jersey sires than Holstein sires. The Jersey sires had similar weighted mean PTA for udder depth (**UD**) as Holstein sires, and the weighted mean PTA of the Jersey sires for foot angle (**FA**) suggest the Jersey sires would transmit somewhat steeper foot angle than Holstein sires relative to breed means.

Successful crossbreeding programs require the use of high-ranking sires within breed based on indexes such as Net Merit (McAllister, 2002). Some dairy producers might interpret the benefits of crossbreeding as justification to use natural service bulls rather than AI. The continuous use of progeny-tested and highly ranked AI bulls is critical to genetic improvement regardless of mating system. All service sires in this study were above the 90th percentile for Net Merit within breed at the time of selection; however, the weighted mean for Net Merit of sires in May 2007 was the 37th percentile for Jersey and the 60th percentile for Holstein. Therefore, J×H were disadvantaged compared with the pure Holsteins in this study for rank of sires for Net Merit.

Production and SCS

Standard edits were applied to test-day observations for production and SCS, and they were similar to those

used by the USDA for routine genetic evaluation and those described in Heins et al. (2006c). Lactations of cows were required to be at least 40 d in milk. If a cow died or was culled, the lactation was required to have at least 15 d. For individual test days, DIM was required to be from 5 to 365 d. The first test after 305 d, but not beyond 365 d, was included in the data. Each test day was required to have an observation for milk, fat, and protein production. Fat percentage was required to be at least 1.0%, but no more than 9.9%. Protein percentage was required to be at least 1.0%, but no more than 6.0%.

Actual milk, fat, and protein production for 305-d lactations were calculated with Best Prediction (**BP**), which was implemented by AIPL in February 1999 for national genetic evaluation in the United States (VanRaden, 1997). The BP adjusted for age at calving and, for lactations less than 305 d, BP projected records to 305 d. The BP was applied separately to each of the 2 locations in this study, and location-specific lactation curves were used to calculate 305-d actual production. Somatic cell score was calculated by averaging the SCS across all test days in first lactation. All cows in this study were milked twice daily.

Dependent variables for statistical analysis were 305-d milk, fat, and protein production, as well as fat plus protein production and SCS. Independent variables were effects of location, season nested within location, and breed group. The GLM procedure of SAS (SAS Institute, 2004) was used to obtain solutions and conduct the ANOVA. Preliminary analysis indicated that interaction of location and breed group was not significant ($P > 0.57$).

CR, DO, and PP

The CR was recorded in a binary manner as either conceived or not conceived for all services, and services from 1 to 6 were included in the analysis. Two cows from each breed group were culled before first breeding and 74 J×H were compared with 71 pure Holsteins for CR.

The DO of J×H and pure Holsteins was measured as actual DO for first-calf heifers with pregnancy status confirmed by ultrasound and reconfirmed, when possible, with a subsequent date of calving. To be included in the analysis for DO, first-calf heifers were required to have at least 250 DIM as required in the United States for genetic evaluation (VanRaden et al., 2004). Unadjusted DO ranged from 48 to 509 d; however, cows with more than 250 d for DO had DO set to 250 d. Records of at least 250 d and the maximum of 250 d for DO are used by USDA-AIPL for genetic evaluations for cow fertility in the United States (VanRaden et al., 2004). After edits, 70 J×H were compared with 67 pure Holsteins for DO.

The J×H and pure Holstein cows were compared for 3 thresholds of pregnancy within fixed intervals of time: 120, 150, and 180 d postpartum. The PP was recorded in a binary manner as either conceived or not conceived within each fixed interval (120, 150, and 180 d) postpartum; and 76 J×H were compared with 73 pure Holsteins.

Independent variables for statistical analysis of CR, DO, and PP were the fixed effects of location, season nested within location, and breed group. Once again, preliminary analysis indicated interaction of location and breed group was not significant ($P > 0.09$). For CR, the MIXED procedure (SAS Institute, 2004) was used with cow as a random effect and service number was included as a covariable in the statistical model. For DO and PP, the GLM procedure (SAS Institute, 2004) was used to obtain solutions. However, the GLIMMIX procedure was used to determine the statistical significance for CR and the LOGISTIC procedure (SAS Institute, 2004) was used to determine statistical significance for PP because both were binary traits. Significance of contrasts between breed groups for CR and PP were from the logistic regression analysis. For DO, a χ^2 test (SAS Institute, 2004) was conducted for breed group and stratifications of DO.

Body and Udder Measurements

Body measurements were BW at calving, BCS, hip height, heart girth, thurl width, pin width, rump angle, foot angle, and foot length. Except for BCS, all body measurements were objectively recorded. Udder measurements were rear udder height (RUH), rear udder width (RUW), udder clearance, front teat placement (FTP), and teat length (TL). Body weights were recorded

within 12 h of calving at both SP and MO; however, 4 J×H were not weighed within 12 h postpartum and could not be included in the analysis. All other body measurements were recorded on cows between 40 and 191 d postpartum. Two cows from each breed group were culled before measurement. One J×H was culled for disposition and the other was culled due to an injury. The 2 pure Holsteins were culled for toxic mastitis. Therefore, 74 J×H and 71 pure Holsteins remained for comparison.

For foot measurements, 1 J×H and 3 pure Holsteins were not recorded because cows were treated for foot disorders and unable to have foot measurements recorded. The BCS was measured by one person on a 1-to-5 scale, with 1 = excessively thin and 5 = excessively fat, in increments of 0.25 (Wildman et al., 1982). Rump angle was measured as the levelness from hooks to pins, with a rump angle of 0.0 indicating perfect levelness from hooks to pins. Foot angle was measured by placing a protractor on the middle front of the hoof, and foot length was measured with a ruler from the hairline to the tip of the hoof. Both foot measurements were recorded on the hind foot nearest the pit in the milking parlor.

For udder measurements, RUH was distance from the bottom of the vulva to the top of the rear udder, and RUW was measured as udder width at the top of the rear udder. Udder clearance was measured from the ground to the bottom of the udder, FTP was the distance between the base of the front teats, and TL was the length of front teats.

Independent variables for statistical analysis of BW, BCS, hip height, heart girth, thurl width, pin width, rump angle, foot angle, foot length, RUH, RUW, udder clearance, FTP, and TL were the fixed effects of location, season nested within location, and breed group. For all body and udder measurements except BW at calving, DIM at time of measurement was a covariable in the statistical model. For all body and udder measurements, the GLM procedure (SAS Institute, 2004) was used to obtain solutions and conduct the ANOVA.

RESULTS AND DISCUSSION

Production and SCS

Location and season nested within location were significant ($P < 0.01$) for milk, fat, and protein production as well as fat plus protein production across breed groups (Table 2). For analysis of SCS, location was the only independent variable to achieve significance ($P < 0.05$). The 2 locations differed for SCS (2.79 at SP vs. 3.38 at MO), which is consistent with the results of White et al. (2001) and Kolver and Muller (1998), who reported that grazing herds tended to have greater SCS than confinement herds.

Table 2. Least squares means and standard errors of means for 305-d actual production and SCS during first lactation for St. Paul and Morris locations¹

Item	St. Paul (n = 42)		Morris (n = 107)	
	Mean	SE	Mean	SE
Milk (kg)**	8,444	122.6	6,408	76.7
Fat (kg)**	321	4.3	230	2.7
Protein (kg)**	256	3.7	205	2.3
Fat + protein (kg)**	577	6.3	434	6.0
SCS*	2.79	0.20	3.38	0.13

¹For difference between locations: * $P < 0.05$; ** $P < 0.01$.

Table 2 has least squares means and standard errors for production and SCS, and cows at SP had significantly ($P < 0.01$) greater milk production (8,444 vs. 6,408 kg) than cows at MO during first lactation. For this study, cows at SP (321 kg) had significantly ($P < 0.01$) greater fat production across breed groups than cows at MO (230 kg) during first lactation. Moreover, cows at SP had significantly ($P < 0.01$) greater protein production than cows at MO (256 vs. 205 kg).

Table 3 has number of observations, least squares means, and standard errors for 305-d production and SCS for breed groups. The J×H (7,147 kg) had less milk production ($P < 0.01$) than pure Holsteins (7,705 kg), which is similar to the results of Bryant et al. (2007), Madgwick and Goddard (1989), and Lesmeister et al. (2000b). Normande × Holstein, Montbeliarde × Holstein, and Scandinavian Red × Holstein crossbred cows also had significantly less milk volume than pure Holsteins according to Heins et al. (2006c).

The J×H (274 kg) were not different ($P > 0.05$) from pure Holstein (277 kg) cows for fat production in this study. The fat percentages were 3.83 and 3.59%, respectively, for the J×H and pure Holstein cows. Results for fat production agreed with results of Ahlborn-Breier and Hohenboken (1991) and VanRaden and Sanders (2003), who reported that J×H had similar fat production compared with pure Holsteins.

Table 3. Number of observations, least squares means, and standard errors of means for 305-d actual production and SCS during first lactation of Jersey × Holstein crossbreds and pure Holsteins¹

Item	Jersey × Holstein (n = 76)		Pure Holstein (n = 73)	
	Mean	SE	Mean	SE
Milk (kg)**	7,147	94.9	7,705	100.4
Fat (kg)	274	3.4	277	3.5
Protein (kg)**	223	2.9	238	3.0
Fat + protein (kg)*	497	6.0	515	6.3
SCS	3.22	0.16	2.95	0.17

¹For difference of breed groups: * $P < 0.05$; ** $P < 0.01$.

Table 4. Number of observations, least squares means, and standard errors of means for conception rate¹ and days open of first-calf heifers for breed groups

Item	Jersey × Holstein			Pure Holstein		
	n	Mean	SE	n	Mean	SE
Conception rate (%)	74	58	6.0	71	53	7.0
Days open ² (d)	70	127	8.6	67	150	9.1

¹Paired contrasts were used to compare Jersey × Holstein crossbreds with pure Holsteins.

² $P < 0.10$ for difference of breed groups.

For protein production, J×H (223 kg) were significantly ($P < 0.01$) lower than pure Holsteins (238 kg). Protein percentage for the J×H was 3.12% compared with 3.08% for the pure Holsteins and was similar to results reported by Rincon et al. (1982), who reported that Brown Swiss × Holstein crossbreds had greater protein percentages than pure Holsteins. Lesmeister et al. (2000a) reported that J×H had significantly lower protein production than pure Holsteins; however, VanRaden and Sanders (2003) reported that J×H had similar protein production (0.92 vs. 0.94 kg/d) compared with pure Holsteins.

Fat (kg) plus protein (kg) was used to measure the overall productivity of crossbreds vs. pure Holsteins. The J×H (497 kg) had significantly ($P < 0.05$) less fat plus protein production than pure Holsteins (515 kg) during first lactation. On a percentage basis, J×H had 3.5% less lactational fat plus protein production than pure Holsteins. Heins et al. (2006c) reported Normande × Holstein (8.6% less than pure Holsteins) and Montbeliarde × Holstein (3.8% less than pure Holsteins) crossbreds had significantly less fat plus protein production; however, Scandinavian Red × Holstein crossbreds (2.2% less than pure Holsteins) did not differ significantly ($P > 0.05$) from pure Holsteins for fat plus protein production.

Least squares means for SCS were not significantly different ($P > 0.05$) for the J×H (3.22) vs. the pure Holsteins (2.95) during first lactation. Jerseys have a greater breed average for SCS than Holsteins in the United States (<http://aipl.arsusda.gov>), and the J×H in this study tended to be greater for SCS than the pure Holsteins. Dechow et al. (2007) found no difference for SCS during first lactation for Brown Swiss × Holstein crossbreds compared with pure Holsteins.

CR and DO

Table 4 has number of observations, least squares means, and standard errors for CR and DO during first lactation. Season nested with location and breed group did not significantly explain variation of CR; however, location significantly ($P < 0.01$) accounted for variation

of CR. Cows at SP had significantly ($P < 0.01$) greater CR than cows at MO (65 vs. 46%). Kearney et al. (2004) reported that confinement herds had fewer services per conception than grazing herds; however, Washburn et al. (2002) found no difference in CR between confinement and grazing herds.

The J×H (58%) were not significantly different from pure Holsteins (53%) for CR during first lactation, which is in agreement with Touchberry (1992) and McDowell (1982), who reported no significant difference for CR of crossbreds vs. purebreds. Heins et al. (2006b) found no significant difference in first-service CR of Scandinavian Red × Holstein crossbreds compared with pure Holsteins in 7 dairies in California; however, both Normande × Holstein and Montbeliarde × Holstein crossbreds in that study had greater CR than pure Holsteins. In a survey by Weigel and Barlass (2003), dairy producers indicated that J×H had greater CR than pure Holsteins.

Location significantly ($P < 0.01$) explained variation of DO, but season nested within location was not significant for DO. Cows at SP had significantly ($P < 0.01$) fewer days open than cows at MO (120 vs. 157 d), which is in agreement with Kearney et al. (2004), who found that confinement herds had fewer days open than grazing herds. The J×H tended ($P < 0.10$) to have fewer mean DO (127 ± 8.6 d) than the pure Holsteins (150 ± 9.1 d) during first lactation, which is in agreement with Heins et al. (2006b), who reported that Normande × Holstein, Montbeliarde × Holstein, and Scandinavian Red × Holstein crossbreds had 19 to 27 fewer DO than pure Holsteins. In the present study, J×H had 23 d fewer DO than pure Holsteins during first lactation.

First-calf Brown Swiss × Holstein crossbreds had 17 fewer DO than pure Holsteins for Dechow et al. (2007). Also, McDowell et al. (1970) and Brandt et al. (1974) reported Brown Swiss × Holstein crossbreds had fewer DO than pure Holsteins. However, Touchberry (1992) reported Guernsey × Holstein crossbreds had 3 d more DO than pure Holsteins.

The difference of J×H vs. pure Holsteins for DO in this study was greater than expected from breed differences and heterosis estimates of VanRaden et al. (2007). Mean DO of the pure Holsteins in this study averaged 150 d during first lactation, which is similar to the average DO for Minnesota herds (143 d) reported by Oseni et al. (2003). However, the Holsteins in the present study had less DO than the Minnesota DHI average for DO of 166 d (Minnesota DHI, 2006). Reproductive efficiency has declined in Holsteins worldwide (Lucy, 2001), and selection for milk production has led to an increase in DO of Holstein cows (Oseni et al., 2003; VanRaden et al., 2004).

The percentage of first-calf heifers by breed group and by stratification for DO is in Table 5. The χ^2 test indi-

Table 5. Percentage of first-calf heifers by breed group and stratification for days open¹

Days open (d)	Jersey × Holstein	Pure Holstein
35–99	41	31
100–174	36	25
175–249	6	11
≥250	17	33

¹For difference of breed groups: $P < 0.10$.

cated that the stratifications tended to differ ($P < 0.10$), and 41% of the J×H had DO of 35 to 99 d vs. 31% of the pure Holsteins. Furthermore, only 17% of the J×H had at least 250 d for DO vs. 33% of the pure Holsteins. Fewer pure Holsteins had <100 d for DO and more pure Holsteins had ≥250 d for DO compared with the J×H cows ($P < 0.10$). Heins et al. (2006b) reported that more Normande × Holstein, Montbeliarde × Holstein, and Scandinavian Red × Holstein crossbred cows had DO <100 d than pure Holsteins and more pure Holsteins had ≥250 d for DO, which is similar to the results in this study.

PP

Table 6 has number of observations, least squares means, standard errors, and significance from the statistical test from logistical regression for breed groups for proportion of cows pregnant within 120, 150, and 180 d postpartum during first lactation. Location significantly ($P < 0.05$) explained variation of PP at 150 and 180 d postpartum, but season nested within location was not significant for any interval of PP. The J×H did not differ ($P > 0.10$) from pure Holsteins for PP at 120 d (57 vs. 51%); however, at 150 and 180 d postpartum, significantly ($P < 0.05$) more J×H crossbreds were pregnant than pure Holsteins. At 150 d postpartum, 75% of J×H were pregnant compared with only 59% of pure Holsteins. At 180 d postpartum, 77% of J×H were pregnant compared with 61% of pure Holsteins.

Table 6. Number of observations, least squares means, and standard errors of means for proportion of cows pregnant within fixed intervals from calving of first-calf heifers for breed groups¹

Days postpartum	Jersey × Holstein (n = 76)		Pure Holstein (n = 73)	
	Mean	SE	Mean	SE
	(% pregnant)			
120 d	57	6.0	51	6.0
150 d ²	75	6.0	59	6.0
180 d ²	77	5.0	61	6.0

¹Paired contrasts were used to compare Jersey × Holstein crossbreds with pure Holsteins.

² $P < 0.05$ for difference of breed groups.

Table 7. Number of observations, least squares means, and standard errors of means for body measurements and udder measurements of first-calf heifers for breed groups¹

Item	Jersey × Holstein			Pure Holstein		
	n	Mean	SE	n	Mean	SE
Measurement						
BW** (kg)	72	463	5.96	73	523	6.29
BCS*	74	2.80	0.03	71	2.71	0.03
Hip height** (cm)	74	133.6	0.46	71	142.5	0.47
Heart girth** (cm)	74	178.0	1.95	71	189.8	1.97
Thurl width** (cm)	74	46.6	0.26	71	50.5	0.26
Pin width** (cm)	74	11.2	0.17	71	12.4	0.17
Rump angle (cm)	74	6.0	0.34	71	5.7	0.35
Foot angle* (degrees)	73	41.6	0.53	68	43.4	0.55
Foot length† (cm)	73	7.6	0.08	68	7.4	0.08
Udder measurement						
Rear udder height (cm)	74	15.4	0.38	71	15.2	0.38
Rear udder width (cm)	74	8.9	0.26	71	9.4	0.27
Udder clearance** (cm)	74	47.7	0.53	71	54.6	0.53
Front teat placement ** (cm)	74	15.8	0.46	71	14.0	0.47
Teat length (cm)	74	4.5	0.08	71	4.5	0.08

¹For difference of breed groups: † $P < 0.10$; * $P < 0.05$; ** $P < 0.01$.

Our results are similar to those of McDowell et al. (1970), who reported that Ayrshire × Holstein and Brown Swiss × Holstein crossbreds had greater proportions of cows pregnant at 120 and 145 d postpartum. Additionally, McDowell et al. (1974) reported greater proportions of crossbred cows pregnant at 200 d postpartum than pure Holsteins.

Body Measurements

Table 7 has number of observations, least squares means, and standard errors of J×H and pure Holsteins for body measurements during first lactation. Season nested within location significantly ($P < 0.05$) influenced all body measurements, and location was significant ($P < 0.05$) for thurl width, pin width, rump angle, BCS, and foot length. Days in milk explained significant variation ($P < 0.05$) only for foot length, which increased with DIM. Cows at SP had greater thurl width (49.1 vs. 48.0 cm), greater pin width (12.2 vs. 11.5 cm), greater rump angle scores (7.2 vs. 4.5 cm), and greater hoof length (7.8 vs. 7.2 cm) than cows at MO. The results are consistent with Boettcher et al. (2003) who found that grazing herds had cows with more favorable foot and leg scores than confinement herds; however, cows in grazing herds did not differ from confinement herds for frame and capacity. At the time of calving, cows at SP and MO did not differ for BW (499 vs. 487 kg), which agrees with results of Washburn et al. (2002). Immediately after calving, J×H (463 kg) weighed significantly ($P < 0.01$) less than pure Holsteins (523 kg). Touchberry and Batra (1976) and Touchberry and Bereskin (1966) found similar results and reported that Guernsey × Holstein crossbreds had lower BW at calving than pure Holsteins.

The J×H (2.80) had significantly ($P < 0.05$) greater BCS than pure Holsteins (2.71). Mean BCS for the pure Holsteins in this study was lower than reported by Dechow et al. (2001), who found an average BCS of 3.18 for over 17,000 first-calf Holstein heifers. Mean BCS for cows at SP (2.86) was significantly greater ($P < 0.01$) than for cows at MO (2.64). Kolver and Muller (1998) found lower BCS among Holsteins than in this study and reported that grazing cows had significantly lower BCS than confined cows, which is in agreement with our study. McDowell and McDaniel (1968) reported Brown Swiss × Holstein and Ayrshire × Brown Swiss crossbreds tended to have greater BCS than pure Holsteins.

For hip height and heart girth, J×H were significantly ($P < 0.01$) smaller in stature (133.6 vs. 142.5 cm) and had significantly ($P < 0.01$) less heart girth (178.0 vs. 189.8 cm) than pure Holsteins during first lactation. Furthermore, J×H had significantly ($P < 0.01$) less thurl width (46.6 vs. 50.5 cm) and significantly ($P < 0.01$) less pin width (11.2 vs. 12.4 cm) than pure Holsteins. McDowell (1982) found Ayrshire × Holstein and Brown Swiss × Holstein crossbreds had less stature at the withers and had less heart girth than pure Holsteins. Furthermore, Touchberry and Bereskin (1966) reported that Guernsey × Holstein crossbreds had less wither height and heart girth than pure Holsteins.

The J×H (6.0 cm) did not differ from pure Holsteins (5.7 cm) for rump angle, which is consistent with the results of McDowell and McDaniel (1968). Rump angle scores in this study indicate a moderate slope from hooks to pins for both J×H and pure Holsteins.

For foot angle, J×H (41.6°) had significantly ($P < 0.05$) lower foot angle than pure Holsteins (43.4°). Although not significantly different, J×H tended ($P = 0.08$) to have

longer hoof lengths (7.6 vs. 7.4 cm) than did pure Holsteins. Variation in body size is a concern of dairy producers with crossbred animals (Weigel and Barlass, 2003), and J×H in this study had lower BW at calving, as well as reduced hip heights, heart girths, thurl widths, and pin widths, compared with pure Holsteins during first lactation.

Udder Measurements

Table 7 also has number of observations, least squares means, and standard errors for udder measurements during first lactation. Location significantly ($P < 0.01$) explained variation for RUH, FTP, and TL, and season nested within location was significant ($P < 0.01$) only for FTP and TL across breed groups. Cows at SP had significantly ($P < 0.05$) less RUH (14.4 vs. 16.2 cm), greater FTP (15.9 vs. 14.0 cm), and greater TL (4.7 vs. 4.3 cm) than cows at MO. Boettcher et al. (2003) reported that cows in grazing herds in Canada had superior mammary systems compared with cows in confinement herds. Udder clearance would be expected to be greater for grazing vs. confinement herds, because grazing herds tend to have lower production; however, locations were not significantly different for udder clearance in this study.

The J×H were not significantly different from pure Holsteins for RUH (15.4 vs. 15.2 cm), RUW (8.9 vs. 9.4 cm), and TL (4.5 vs. 4.5 cm). The J×H (47.7 cm) had significantly ($P < 0.01$) less udder clearance than pure Holsteins (54.6 cm); however, the J×H were 8.9 cm shorter in stature than the pure Holsteins. Furthermore, the J×H had significantly ($P < 0.01$) greater distances between the front teats (15.8 vs. 14.0 cm). Few studies have reported on differences of crossbreds and purebreds for udder measurements. A study with a research herd at USDA-Beltsville found that Ayrshire × Holstein and Brown Swiss × Holstein crossbreds had greater udder depth and lower RUH, although no difference in teat placement was reported for crossbreds vs. purebreds (McDowell and McDaniel, 1968).

CONCLUSIONS

Dairy producers in most regions of the United States have been paid increasingly on the solids in milk and decreasingly on fluid volume. Therefore, milk volume is not an adequate basis for comparing crossbreds with pure Holsteins. In this study, J×H were not different from pure Holsteins for lactational fat production during first lactation; however, J×H were significantly lower (−3.5%) than pure Holsteins for fat plus protein production.

The reproductive decline of pure Holsteins around the world in recent years has resulted in interest in cross-

breeding of dairy cattle. Heterosis for fertility is typically substantial for livestock, and the J×H in this study had a 23-d advantage for DO. Generally, recent research including Heins et al. (2006b) and Dechow et al. (2007) has suggested a 2- to 3-wk advantage of crossbreds vs. pure Holsteins for DO, which should enhance the profitability of dairy production systems.

The means of breed groups for 305-d production in this study were not adjusted for differences in DO, and cows with fewer DO are penalized for 305-d production compared with cows with longer DO. Adjustment for breed group differences in current DO would bring the production of the J×H closer to the production of the pure Holsteins.

Few research studies have compared crossbreds to pure Holsteins for body and udder measurements, and those studies are dated (McDowell, 1982; Touchberry, 1992). The J×H in this study had 60 kg less BW immediately postpartum and had reduced hip height, heart girth, thurl width, and pin width during first lactation. Moreover, the advantage in BCS of the J×H compared with pure Holsteins in this study might have contributed to the enhanced fertility of the crossbreds. The smaller body size of J×H should provide benefits in lowering maintenance costs compared with pure Holsteins.

Udder traits are important for functional milk production, and the J×H in this study had 6.9 cm less udder clearance and 1.8 cm greater FTP; however, these modest differences for udder conformation did not result in premature culling of the J×H during first lactation. Documentation of type traits of crossbreds compared with pure Holsteins is important, because results might influence decisions regarding specific breeds for crossbreeding.

The results of this study suggest that there is little if any difference in lactational fat production and an improvement in fertility when Holstein heifers are mated to Jersey sires to initiate first lactation. Additional research with cows in this study will compare all lactations of J×H vs. pure Holsteins for calving difficulty and stillbirth, production, fertility, health, survival, and body and udder measurements. Total economic impact of all traits from birth to removal from the herd must be evaluated to determine if J×H have a role to play in the dairy industry.

The Jersey and Holstein breeds are only 2 of numerous breeds for consideration in crossbreeding systems for dairy cattle. Results of research will provide guidance to dairy producers for selection among alternative breeds of dairy cattle for specific management systems. Irrespective of breed, the continuous use of highly ranked AI sires within breed is critical.

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